Faculty of Manufacturing Engineering

ACCELERATED WEATHERING OF RUBBERWOOD REINFORCED RECYCLED POLYPROPYLENE COMPOSITES

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Master of Manufacturing Engineering (Industrial)

2019

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A thesis submitted
in fulfillment of the requirements for the degree of of Master of Manufacturing Engineering (Industrial Engineering)

Faculty of Manufacturing Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2019

DECLARATION

I declare that this thesis entitled "accelerated weathering of rubber wood reinforced recycled polypropylene composites" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : .....

Date : .....

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Manufacturing Engineering.

Signature:……..

Supervisor Name:……

Date:…….

DEDICATION

I dedicate this thesis to God almighty for the grace and wisdom given by him to pursue my master degree and also to my beloved mother, father and my darling wife for their supports and encouragement.

ABSTRACT

The purpose of this paper is to study the effects of water immersion-freeze-thaw treatment on the physical properties, flexural strength (FS) and morphology of wood-polypropylene composites. The behaviour of wood plastic composite is difficult to predict due to the complexity in the structure of the material. Wood consists of cells (fibres) arranged in an intricate pattern, and the behaviour of the material is a result of the behaviour of the cells and the cell arrangement. In this thesis, different approach will be employed to analyze various degradation in wood plastic composite. This study will revealed whether the flexural strength and dimensional stability of the wpc will decrease or increase after exposure to water immersion-freeze-thaw cycling and water absorption fatigue, also the degree of changes in the surface properties (colour and roughness) of the composites after exposure to water immersion-freeze-thaw cycling. This study is a part of an ongoing study on weathering of wood-polymer composites (WPC), the results of this study will be obtained from accelerated laboratory experiments.

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The purpose of this paper is to study the effects of water immersion-freeze-thaw treatment on the physical properties, flexural strength (FS) and morphology of wood-polypropylene composites. The behaviour of wood plastic composite is difficult to predict due to the complexity in the structure of the material. Wood consists of cells (fibres) arranged in an intricate pattern, and the behaviour of the material is a result of the behaviour of the cells and the cell arrangement. In this thesis, different approach will be employed to analyze various degradation in wood plastic composite. This study will revealed whether the flexural strength and dimensional stability of the wpc will decrease or increase after exposure to water immersion-freeze-thaw cycling and water absorption fatigue, also the degree of changes in the surface properties (colour and roughness) of the composites after exposure to water immersion-freeze-thaw cycling. This study is a part of an ongoing study on weathering of wood-polymer composites (WPC), the results of this study will be obtained from accelerated laboratory experiments.

ABSTRAK

Tujuan kertas ini adalah untuk mengkaji kesan rawatan rendaman air-pembekuan air pada sifat fizikal, kekuatan lenturan (FS) dan morfologi komposit kayu-polipropilena. Tingkah laku komposit plastik kayu sukar untuk diramal kerana kerumitan dalam struktur bahan. Kayu terdiri daripada sel-sel (serat) yang diatur dalam corak yang rumit, dan kelakuan bahan adalah hasil dari tingkah laku sel-sel dan susunan sel. Dalam tesis ini, pendekatan yang berbeza akan digunakan untuk menganalisis pelbagai kemerosotan dalam komposit plastik kayu. Kajian ini akan mendedahkan sama ada kekuatan lenturan dan kestabilan dimensi wpc akan berkurang atau meningkat selepas pendedahan kepada litar berbasikal dan membasahi air dan penyerapan air, juga tahap perubahan dalam sifat permukaan (warna dan kekasaran) komposit selepas pendedahan kepada basikal cair-beku-cair. Kajian ini adalah sebahagian daripada kajian berterusan mengenai pelepasan komposit kayu-polimer (WPC), hasil kajian ini akan diperolehi daripada percubaan percubaan makmal.

ACKNOWLEDGEMENTS

I would like to take this opportunity to express my sincere acknowledgement to my supervisor Dr. Zaleha Binti Mustafa from the Faculty of Manufacturing Engineering Universiti Teknikal Malaysia Melaka (UTeM) for his essential supervision, support and encouragement towards the completion of the first phase of this thesis.

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PMC	-	Polymer matrix composite
FRP	-	Fibre reinforced plastic
PP	-	Polypropylene
PE	-	Polyethylene
ASTM	-	American society for testing and material
MAPP	-	Maleic anhydride graft polypropylene
Curv	-	Self-reinforced polypropylene prepreg
L_c	-	Critical length
D	-	Diameter
V_f	-	Fibre volume fraction
ρ_c	-	Density of composite laminate
W_f	-	Fibre weight fraction
ρ_f	-	Fibre density
ρ_T	-	Theoretical density of composite laminate
ρ_{Exp}	-	Experimental density of composite laminate
W_c	-	Composite weight
E	-	Modulus of elasticity/Young modulus
ε_{ult}	-	Ultimate strain

Chapter 1

1.0 INTRODUCTION

1.1 Background

The wood/plastic composite (WPC) is an environment-friendly composite with high performance and added value. It is made from wood flour (WF) and thermoplastic mixed with a certain proportion of coupling agent, lubricant, stabilizer, etc. under injection moulding, extrusion and another forming process. WPC shares the wood texture of original solid wood products as well as excellent mechanical properties, workability, corrosion resistance, water tolerance, fireproofing, etc.

Its earliest popularization and applications can be dated to 1980s in America. Presently, it has been widely used in decoration, automobile interior, public infrastructure, furniture material, warehouse logistics, consumptive durable products, electronic products and so on. As the wood flour is a major component of WPC, the governments have been strongly encouraging and promoting the development and applications of wood/plastic products in recent years in order to facilitate recycling of waste plastics and reduce the consumption of forest resources.

Under the background of scale commercialized application of wood/plastic products, it has become a research hotspot to improve the quality and cut down the production cost of the wood/plastic products. The principal research approaches include increasing the additive amount of wood flour, reducing the additive amount of plastics, adding padding, and improving the production process.

Wood plastic composites (WPCs) are relatively new generation of composite materials and also the most promising sector in the field of both composite and plastic industries, traditionally corresponded to a material primarily composed of wood particles and a thermoplastic polymer. At present days, the concept is broader and the term WPC refers to any composites that contain plant fibres and thermoset or thermoplastic polymers. Since the chemical and physical properties of the main components are different, this type of composite usually contains additives to enhance the bonding between the polymeric matrix and the fibres. The higher strength and aspect ratio of natural fibres offers good reinforcing potential in composite matrix compared to the artificial fibres.

Regarding the selection criteria of polymer types for the composites, thermoplastics are usually preferred over thermoset because they offer the advantage of enabling repeated melting processes, unlike thermosetting polymers which become irreversibly in the solid state after a single processing cycle that leads to polymerization after an initial increased temperature. Thermoplastics are most adequate for blending the vegetable fibres and obtaining the composites in a twin screw extruder, for instance, followed by the extrusion or injection moulding of the composite previously obtained to achieve the intended final products. The great evolution of the WPCs has occurred together with the development of new processing methods and technologies, as well as the development of new designs for most traditional products. Thus, the innovative WPCs have inspired new solutions for the surrounding industries in the fields of construction, architecture, automotive, decoration, among many others (Friedrich and Luible 2016a)

The WPC concept has been continuously evolving, addressing innovative solutions to the challenges derived from growing environmental impacts of hazardous chemical substances and excessive energy consumption. Awareness of these problems, which may be associated to a variety of industrial, scientific and political options, as contributed to the

development of “green chemistry” solutions to maximize the efficiency of use of raw materials and to minimize the creation of waste.

Emissions from these sectors are more likely to be self-generated, being induced more by sector-specific supply factors that led to own value-added economic growth. Therefore, initiatives targeting the production side (such as economic incentives that induce the use of energy-saving technologies) are the more appropriate measures for low CO_2 emissions. Production-side measures and incentives are also recommended for the Construction sector, which is a secondary key sector due to the significant total effect (Sharliza et al. 2010).

The energetic performance of buildings is, indeed, a matter of major concern in modern architecture. In this context, the interior and exterior system for buildings have emerged as key elements in the design; providing not only thermal comfort, controlled luminosity and protection against other environmental conditions, but also enabling various aesthetic effects regarding both the exterior and the interior spaces. In fact, using wood plastic for external and internal design enable changeable levels of exposure and simultaneously alter the outlook of the design. However, the existing systems have a poor performance and available commercial solutions are characterized by limited standardized models. Therefore new developments in wood technology are required, being time to put in the market new concepts of architectural applications and take them to the forefront of architecture and design.

The actual demand for sustainable construction has fostered the research of alternative products, namely based on composite materials resulting from the use of renewable material and/or industrial wastes, conventionally called "green materials" (Friedrich and Luible 2016a). Wood plastic composites (WPC) constitute emblematic

examples of materials that seek to address some environmental issues related to the construction sector, since they may be composed of renewable thermoplastics, such as polyethylene, and industrial wood wastes, such as pine sawdust, to generate value-added products. In fact, the reuse and recycling of materials for new applications and processes are of great importance because they allow for the closing of the production cycle to reduce energy consumption at the level of extraction and processing of raw materials, assuming these wastes and by-products are new materials for new products, thereby initiating a new life cycle of the product (Rahman et al. 2013).

This study will enhance the understanding of the durability of WPCs exposed to accelerated laboratory freeze-thaw cycling. This study will encompass recycled polypropylene. Furthermore, with a single wood mesh size, wood contents, maleates polyethylene content, and wood species rubber wood will be investigated. This will aid in enhancing wood-plastic composites so that they will have a prolonged service life. The conclusions from this study will result in enhanced outdoor durability for WPC building products.

1.2 Problem Statement

Various exposure have been investigated and evidence has shown that there is a potential for degradation of wood-plastic composites via fungi, termites and UV light exposure. Other types of exposure, such as winter climate exposure, have yet to be investigated and could result in other forms of degradation for WPCs. Considerable information is available on the durability of WPCs exposed to warm climate conditions and improvements can be made in the future.

However, the various information on the durability of wood composite in the open literature has left further improvement space. The durability of WPCs to freeze- thaw actions is vital because they are majorly in exterior use in colder regions. The long-term response of wood-plastic composites to environmental influences would ideally be evaluated by real time observations of the materials in natural conditions. These reasons demonstrate that accelerated laboratory freeze-thaw tests are more practical and will be utilized to ascertain the future of WPCs.

1.3 Aim and Objectives

The main goal of this study was to investigate the mechanical properties of wood-plastic composites exposed to accelerate freeze-thaw cycling meant to simulate outdoor exposure to different temperature. This goal will be fulfilled by addressing the following objectives:

The aim of the objectives of this study are:

I. To analyse the effect of the freeze-thaw cycles on the properties of rubber wood recycled polymer composite
II. To determine the effect of the water absorption fatigued on the properties of the rubber wood recycled polymer composite

1.4 SCOPE

To characterize the mechanical, thermal degradation on WPC due to freeze thaw Effect, the characterization is carried out using flexural, hardness, DSC, FTIR and Sem.

To evaluate the stability of the composite due to fatigue water absorption of the wood plastic composite.

The main raw material that will be used during this research are recycled Polypropylene (PP) which will be combined with the wood-flour. Hot press compression molding will be used to fabricate the intended composite. Then, the samples will be freeze-thaw for up to three cycles and tested destructively by using the flexural test (ASTM D790), and other physical and chemical testing such as, FTIR analysis, differential scanning calorimetric (ASTM D3418-15), scanning electron microscopy and fatigue water absorption. All of the test procedures are in accordance to the American Standard Testing Method (ASTM) as to ensure the accuracy and reliability of the testing data.

Chapter 2

2.0 LITERATURE REVIEW

2.1 INTRODUCTION

Wood is one of the most abundant and readily available resources used all over the world for building materials. However, there are several factors that need to be addressed when considering the use of rubber wood. Among the basic concepts to understand how to appropriately utilize wood are the variations in structure between species, effects of atmospheric conditions, the susceptibility to biological organisms, and preservative chemicals.

Rubber tree (Hevea brasiliensis) is widely planted in malaysia for the production of latex, and is cut down when it becomes unproductive at about 25 years of age. Rubber wood lumber is mainly used to produce furniture, toys, and packing materials. In rubber wood industries, a large amount of wood waste in the forms of flour, sawdust, and chips, is generated at different stages of processing. Generally, rubber wood waste is dumped in landfills or burned, but some of the waste is also used to produce medium density fiber board and particleboard. The utilization of rubber wood waste as a filler in polymer composites could decrease environmental impacts from the waste, as well as add value

when contributing to the composite properties (Homkhiew, Ratanawilai, and Thongruang et al. 2014).

2.1.1 Properties of rubber wood

Important properties for consideration with wood include compressive, tensile, and flexural strength and stiffness, impact strength, durability, shear strength and toughness. Rubber wood is a Light Hardwood with a density of 560-640 kg/m^3 air dry. The timber is moderately hard and light to moderately heavy.

Rubber wood in its natural form is classified as non-durable. It is very susceptible to attack by fungi and insects. Bio-deterioration starts almost immediately after the tree is felled. Blue stain fungi penetrate the ends of logs within a week of felling and the infection is found to be more severe during the raining season. Texture is moderately coarse but even, with straight to shallowly interlocked grain (Green Winandy, J. E. and Kretschmann, D. E. 1999).

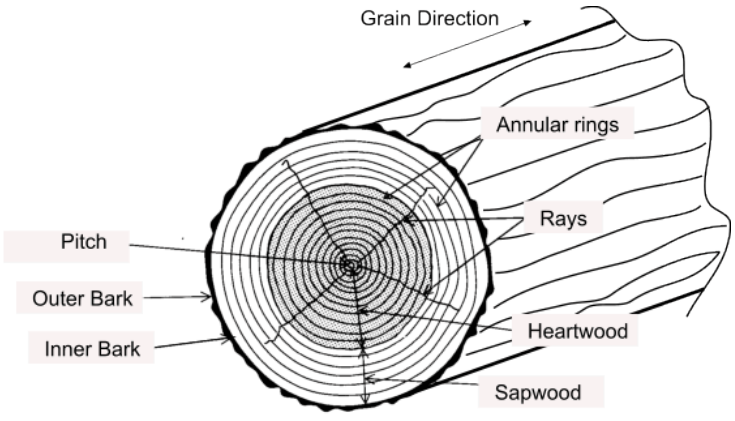

Figure 2.1 rubber wood structure

2.1.2 Deterioration of Wood

Since wood is part of a natural and organic environment, it is susceptible to degradation from many types of organisms, some of which were previously mentioned. The mechanical and physical properties of a wood element and mostly of wooden structure can and will be affected by a combination between moisture content, temperature, biological activities etc (Teodorescu et al. 2017). According to Teodorescu report, the life duration of a material depends on the relative humidity in different combinations with temperature and exposure time. Together, these factors can deteriorate the material by developing mold surfaces.

The surface of wood can be degraded if the wood repeatedly becomes wet and dry, is exposed to high and low temperatures and is exposed to direct sunlight. This degradation causes roughening of the surface, checking, splitting and wood cell erosion. Erosion, caused by the loss of wood cells from the lumber surface, is a slow proces

2.2 Wood plastic composite

Wood plastic composite is a low-carbon and environmentally friendly materials which refers to composite material that contains wood and plastic. Among the numerous advantages of WPCs includes, light weight, corrosion resistance, dimensional stability, and recyclable, which is widely used in outdoor construction, logistics and decoration, etc., WPC products have commonly substituted for solid wood in today's applications, which can effectively solve the waste fiber and plastic products caused by waste of resources and the problems of environment pollution (Ge et al. 2018)